CANADA
DEPARTMENT OF MINES AND TECHNICAL SURVEYS
MINES BRANCH

OTTAWA

FUELS AND MINING PRACTICE DIVISION

INTERNAL REPORT FMP 63/20-PRE

WORKING PARTY ON MOVEMENT OF SOLIDS
REPORT NO. 7

RESEARCH ON THE TRANSPORTATION OF SOLIDS BY MOBILE PIPELINE

by

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January 1963

90-04529/

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ABSTRACT

For the transportation of solids, in the range of 1 to 10 million tons/year, the Mobile Pipeline appears to be a logical and promising solution to the most serious defects of both the conventional pipelines and railways, e.g. the heavy load per unit of pipe or track length, the oversized, inefficiently used and expensive infra-structures (including bridges and tunnels), and the solids size limitations, crushing pressures and slow speeds in pipelines. On the contrary, the Mobile Pipeline may give automatic continuous and fast transportation based on lighter (and cheaper) fixed installations, that support inexpensive and almost endless trains of articulated trough with hinged lids. The driving energy is applied with more continuity and without any pressure through numerous small motors along the line, thus contributing to the maximum efficiency of this new transportation technique.

RECHERCHE SUR LE TRANSPORT DE SOLIDES PAR CANALISATION MOBILE

par

R. P. Charbonnier*

RÉSUMÉ

Pour le transport de solides (de 1 à 10 millions de tonnes par an), la "Canalisation Mobile" semble être une solution, logique et pleine d'avenir, du problème des défauts les plus graves des canalisations et chemins de fer classiques, par example la lourde charge par unité de longueur de voie ou de conduite, les infrastructures excessives, inefficacement utilisées et coûteuses (y compris les ponts et tunnels), et aussi, pour le cas des conduites, les limitations de dimensions des solides, les pressions écrasantes et la vitesse réduite. Au contraire la Canalisation Mobile peut permettre le transport continu, rapide et automatique, basé sur une infrastructure légère et peu coûteuse, portant des trains de goulottes articulées, de faible prix et de très grandes longueurs, munies de convercles pivotants. L'énergie motrice est impartie avec plus de continuité et sans pression par de nombreux petits moteurs le long de la canalisation, ce qui contribue à donner le maximum d'éfficacité à cette nouvelle technique de transport.

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CONTENTS

	Page
Abstract	i
Résumé	ii
Introduction	1
Principle	2
Advantages	4
Limitations	5
Research tests	6
Full size trials	8
Commercial installation	9
Most recent developments	9
Conclusion	12
References	13

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INTRODUCTION

The problems of economic transportation of solids are very important in Canada, especially for coal, ores, minerals, grains, and wood products, over both short and very long distances. Therefore any development, that may improve the economics of such transportation, is of great interest.

Since 1960, the author has been gathering information on a new technique of transportation of bulk materials which has been suggested and developed in France by Jean Hubert et al of the SECCAM (Societe d'etudes et d'exploitation pour le transport continu par canalisation mobile, 7 Place d'Iena, Paris 16). This technique is called the "Mobile Pipeline for continuous conveying". During a field trip in Europe in the summer of 1962, the author has had an opportunity to see some large scale models of this equipment and to discuss its characteristics with SECCAM officials, notably Mr. M. Normand.

The most outstanding features of the mobile pipeline will be described in this report, with a view to the possibilities of its application or adaptation in Canada.

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PRINCIPLE

At present most of the solid materials are usually transported overland by railways, in which very heavy loads are carried over any given section of the track during a very small fraction of the time. Thus excessively important and expensive constructions are required as bridges, tunnels, and ordinary infra-structures of the tracks. In addition, because of the heavy loads, the power requirements are greatly concentrated and the driving energy is difficult to apply through wheels, that have limited adherence coefficients, both for acceleration and for braking; so that the track must never exceed a low slope and a small curve radius, thereby requiring expensive civil engineering structures to accommodate any topographical irregularities and populated areas.

A fairly satisfactory solution to these difficulties has been achieved for liquid and gas materials by the use of pipelines, in which the movement of the liquids and gases is continuous, thereby greatly reducing the instantaneous loads and therefore the costs of bridges, tunnels and generally speaking all the infra-structure. However the driving energy is still applied discontinuously in widely spaced power stations (either with pumps or with compressors), and the high pressures thus obtained require relatively heavy and still expensive pipe and (indirectly) infra-structure. Some solids, even in large sizes, are adequately moved by water pipelines in dredging operations over short distances, and the finer sizes of some

solids are satisfactorily transported in pipelines of two types: water (worthless carrier) and pneumatic (expensive compressed gas) over longer distances, up to about 100 miles. Capsule containers have also been moved in air pipelines (e.g. the extensive pneumatic mail pipeline network in the Paris area) or in water pipelines (e.g. several pipelines for radioactive containers used by the French Atomic Energy Commission).

However in the long pipelines for solids, both the solids and the pipes must withstand very high pressures, unless the pumping stations were excessively increased in numbers, with the corresponding high costs, inefficiency and wear to be expected. Even with low viscosity liquids, the travel velocity is always so low (about 2 meters/ second) that the pipe section must be excessively large for a given tonnage.

The Mobile Pipeline seems to be a logical solution to the worse difficulties of both the conventional pipelines and railways. With this new concept, in order to reduce to the minimum the heavy load per unit of track length of the railway cars, the width and height of the train are reduced to their minimum and its length is extended to the maximum, so that the railway cars are reduced to a very long and light articulated trough (with hinged lids), rolling on a track or preferably suspended on the monorail principle. When empty, this trough is returned on another rail. The driving energy is obtained from numerous small electric motors moving with the trough, along which they are conveniently spaced.

The Mobile Pipeline is also derived from the conventional pipeline by replacing the high internal friction by a low rolling friction (wheels and air surfaces), obtained by moving the pipe itself rather than only the material within. Then the high internal pressures are not needed, thus the pipe and supporting structures can be lighter and cheaper. Furthermore, the driving power can be applied as continuously as possible through a large number of small motors, provided additional power is supplied along any hills by auxiliary motors. However, up to date, the problems of filling and emptying a mobile pipe are not yet solved. For the transportation of hydrocarbons, in arid areas, the pipe could be filled with water for waterflooding the oilfields, on the return trip. Recent research has been concentrated on the mobile trough with tight lids for liquids or powders rather than the mobile pipe.

ADVANTAGES

The main improvement, over both railway and pipeline operations, is obviously the considerable saving in the most important costs of the infrastructure, which is much lighter for the Mobile Pipeline at a given tonnage capacity. Bridges, tunnels, runways are much cheaper, and so are the far smaller power plants for the continuously applied load and drive energy. Considerably sharper gradients and shorter radius curves are allowed than for railways. It has been estimated that the fixed capital investment would be at least 30 to 50% lower than for the cheapest railroads.

In spite of their slight resemblance, the Mobile Pipelines, with carrying capacities of 1 to 10 million tons/ year and over at speeds around 7 to 10 meter/second, can hardly be compared with aerial ropeways, generally limited to 100, 000 to 1 million tons/ year. Then, the reduction in capital expenditure could be estimated at least around 40 to 50% lower for the Mobile Pipelines.

In comparison to the conventional pipelines, the Mobile Pipeline does not require extensive crushing of the solids. In fact, one dimension may be quite long and still suitable for the trough. The higher travelling speeds (e.g. 10 instead of 2 m/ sec) allow a reduction of the pipe section for a given tonnage. Thin and light pipe can be used since it is not under pressure. This also permits friable solids to be transported without crushing or abrasion. The total motive power is reduced with rolling instead of internal friction.

As for conveyor belts, they usually require costly tunnel installations, and much higher driving power. They wear rapidly (often in 6 to 8 thousand hours), they are less adaptable to direction changes and of course cannot be used for liquids. Conveyor belts would seem to cost about twice as much as Mobile Pipelines in capital investment.

LIMITATIONS

The Mobile Pipeline obviously cannot transport economically some types of bulky material that railways can handle, although long but

narrow articles can be suitable for trough conveying. Furthermore, many bulky solids must be crushed to some extent somewhere before reaching the consumers, and it may be feasible to do the crushing (perhaps to a size around 3 inches or less) before transportation rather than after.

The wear of some continuously operated parts may be a limiting factor. However, it may be noted that small electric motors and correctly sized ball bearings are now frequently guaranteed for several dozens of thousands of working hours, i.e. several years of practically continuous operation.

Although the infra structure of the Mobile Pipeline would require less maintenance than a railroad, it is likely to cost more than conventional pipelines in that respect.

Though it would be less affected than the railroad by weather conditions (especially snow), the Mobile Pipeline would naturally be at a disadvantage as compared to the conventional pipelines on this account.

RESEARCH TESTS

The SECCAM organization has built and tested reduced-size models and full scale trial installations of the Mobile Pipeline. At a velocity of 7 m/sec, with a pipe section of $1.\underline{6}$ dm^2, the Mobile Pipeline would have a capacity of 3 million ton/year of a solid of 1.5 density, at a load factor of 2/3 (i.e. the spaces between trains would be half as long as

the trains). This design includes rollers spaced at 3 meter intervals, each carrying an approximate load of 130 kgs. The trough consists of units about 1 to 2 kms long, each including a few hundreds of 3 m long elements with flexible semi-tight connections. Monorail supports at about 100 meter intervals are either of the T type (more stable for curves) or of the V type (increasingly adopted for high voltage lines). Current for the driving motors is supplied by a 1,000 volt three phased line through a small spring-loaded pantograph rubbing on two copper or aluminum wires and through the running rail. Voltages superior to 1,000 volts would create difficult insulation problems for such small motors. The 1,000 volt line is fed approximately every 15 kms through transformers by a higher voltage line, that may be installed above the pipeline on the same supports. The loading of the trough after raising its hinged lids is automatically performed by vibrated chutes, while the pipeline moves underneath them, perhaps at a slower speed. Unloading is also automatic by mechanical tipping, using the longitudinal flexibility of the trough without stopping it. Sidetracks, switch and brake systems have been developed, also an automatic sanding device to increase the adherence of the driving axles whenever needed. Tight troughs and lids have been proposed for the transportation of liquids, but apparently not yet tried on a full scale model. Automatic safety devices to maintain proper spacing between trains have also been designed.

FULL SIZE TRIALS

Starting in November 1959, a test Mobile Pipeline track has been under investigation. It has a length of 125 m, carrying a trough of 14 m length at 7 m/ s, with a section of !. 6 dm ^{2} (3 million tons/ year of ore of 1. 5 density).

Since June 1960, a 720 meter long full-scale loop of two parallel tracks has been under study at Aubigny-sur-Nere, near Paris. It would be suitable for the transportation of 3 million ton/ year of ore having a density of 1. 5. Each of the two parallel trial circuits includes two straight sections of 200 meters, each, connected by two curved sections of 50 meter radius. This installation incorporates upward and downward gradients of 2 percent. The trough (2 mm sheet steel) has a 1. 6 dm^2 section and bears a 25 kg load per linear meter; it is driven at 7 m/ sec by numerous 2 HP squirrel cage electric motors installed at 24 to 30 meter intervals. These motors have a speed of approximately 1000 rpm, and directly rotate wheels of 14 cm of diameter.

An economic survey based on these trials would indicate that, for capacities of one to 10 million tons/ year of solid materials, a Mobile Pipeline would cost considerably less to build than a railroad, with increasing advantage for rough terrain and populated areas, and that it would probably have lower operating expenses.

COMMERCIAL INSTALLATION

The first commercial Mobile Pipeline undertaken with Dorr-Oliver was expected to be operational in 1962. The full benefits of the new design would have been possible, as it was ordered by a mining company (Djebel Onk, Phosphates de Constantine) for the transportation of 1 million tons/ year (with a potential of 3 millions tons/ year) of phosphates from a new mine. The total length of the pipeline would have been 11 kms over mountainous ground, i. e. about 5 kms shorter than the light railway originally planned, and which was estimated to require investments twice as high as the Mobile Pipeline per km of track. It was proposed to use five trains of 900 m length, each train being powered by 43 motors. However this project was in Algeria and could not be carried through under the circumstances prevailing in the early 1960's.

MOST RECENT DEVELOPMENTS

Numerous tests have been conducted in recent years on a large scale. It has been found most desirable to install between each motor and its driving wheel a centrifugal coupling unit, so that the motors always supply their power in the neighbourhood of their running speed, even when starting the Mobile Pipeline. Thus, on a 2% upward gradient, start-up time and distance were respectively 27 seconds and 105 yards without wind, and 100 seconds and 385 yards with a 38 mph headwind.

For grades less than 2% , the variations in speed are not considered excessive: for tests on loaded units, the speed varied from 7.5 m/ s for a 2% down grade, where the motors generate a braking power of 1.3 HP, to 7 m/ sec for a 2% upgrade and for 50 m radius curves, where the motors generate a driving power of 2.4 HP, whereas the synchronous speed of the motors would correspond to 7.33 m/ sec.

A very simple switch system has been built, and gives complete satisfaction. It is based on the elasticity of the rail and works by lever action.

After 6,200 miles of operation, no appreciable wear of any part could be observed.

A new sanding device has been developed to increase the coefficient of adhesion of the driving axles whenever required. The sand is cast onto the rail via a nozzle ahead of the wheel. This device is actuated by a hydraulic system, operated according to the difference in speed between the driving axle and the neighbouring carrying axle.

Driving stations have been built to provide the additional power necessary to overcome steep upward grades without fall in speed and excessive current demands. Thus, over-dimensioning of the regular motors is avoided and, furthermore, it has become possible to overcome grades up to 25%, thereby effecting great savings in the capital investment of a mobile pipeline in irregular topography. The principle is very simple: a cable

carried by two horizontal pulleys travels along the track at a speed of 7 m/s, driven by an electric motor, through a coupler and reduction gear unit. Some of the axles of the Mobile Pipeline are equipped with jaws, normally closed by a powerful spring, which are automatically opened by a cam when arriving close to one of the horizontal pulleys. Immediately after the pulley, the jaw closes on the cable, thus imparting the driving effort of this cable to the trough. The jaw opens again and releases the cable when arriving at the other pulley. The pulley motors are automatically actuated only when the mobile pipeline passes at suitably preselected points. The driving station also helps to brake the mobile pipeline on the down grade, using the same principle of connection.

Short distance mobile pipelines could not have a return loop at each end, as these two loops would require about 1 km together, which would be excessive if the useful length is appreciably less than 10 kms. Then another solution is proposed as follows: at each end of the circuit, a train unit running on a double track instead of a monorail would enter a "barrel" slightly longer than the unit (e.g. 60 m) and rotating through 180° about its horizontal axis. Then the train unit would leave the barrel in an inverted position upside down and could be returned on a going track underneath the coming track, above it, or beside it, as desired.

CONCLUSION

The principle of the Mobile Pipeline seems to be very attractive, especially for the automatic transportation of one to 10 million tons/year of minus 3 inch solids in irregular or populated terrain. The main advantages over other transportation systems would be the lower fixed investments, now estimated at 60 to 80 thousand dollars/km for a Mobile Pipeline of several million tons/year of capacity over rough topography. For instance the Djebel Onk Mobile Pipeline was estimated to require investments of $900,000 against 1.5 million dollars for the equivalent railway. The total cost of transportation by Mobile Pipeline has been estimated at approximately 0.8¢ ton/km.

The SECCAM full scale model research station is estimated to have cost about $200,000 for its installation.

It is hoped that the first commercial Mobile Pipeline will soon be built, perhaps for a Nickel mine in New Caledonia.

In the future, it seems that the fixed investment could be further reduced by adopting smaller safety coefficients, based on experience. The infra structure could be even cheaper than at present, if it is streamlined and simplified to the extreme, and if the driving power is applied with greater continuity by more numerous but lighter motors. Finally if the speed were increased, the whole structure could again be much lighter and cheaper for the same tonnage capacity. Speeds considerably higher than

7 m/ sec would appear feasible to take full benefits of the very promising principles of the Mobile Pipeline.

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